Item P-401, Item P-501 Quality Control, Acceptance Criteria, PWL Concepts

Federal Aviation Administration

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Jeff Rapol, Airport Engineering Division, AAS-100

jeffrey.rapol@faa.gov

Presentation Objectives

- Clarify the process that ESTIMATES Contractor Production Quality using Lot samples.
- Provide brief explanation of PWL concepts and why there is a degree of uncertainty (risk) associated with acceptance plans when small fractions of material are used to evaluate a day's production. (AC 5370-10 Section 110)

Quality Control—Hot Mix and PCC

- Responsibility of Contractor
- Contractor controls processes.
- General Provision Section 100 requires a Contractor Quality Control Program when P-401 or P-501 in the project.
- Specification Items P-401 and P-501 contain minimum items to be included in the Contractor Quality Control Program.

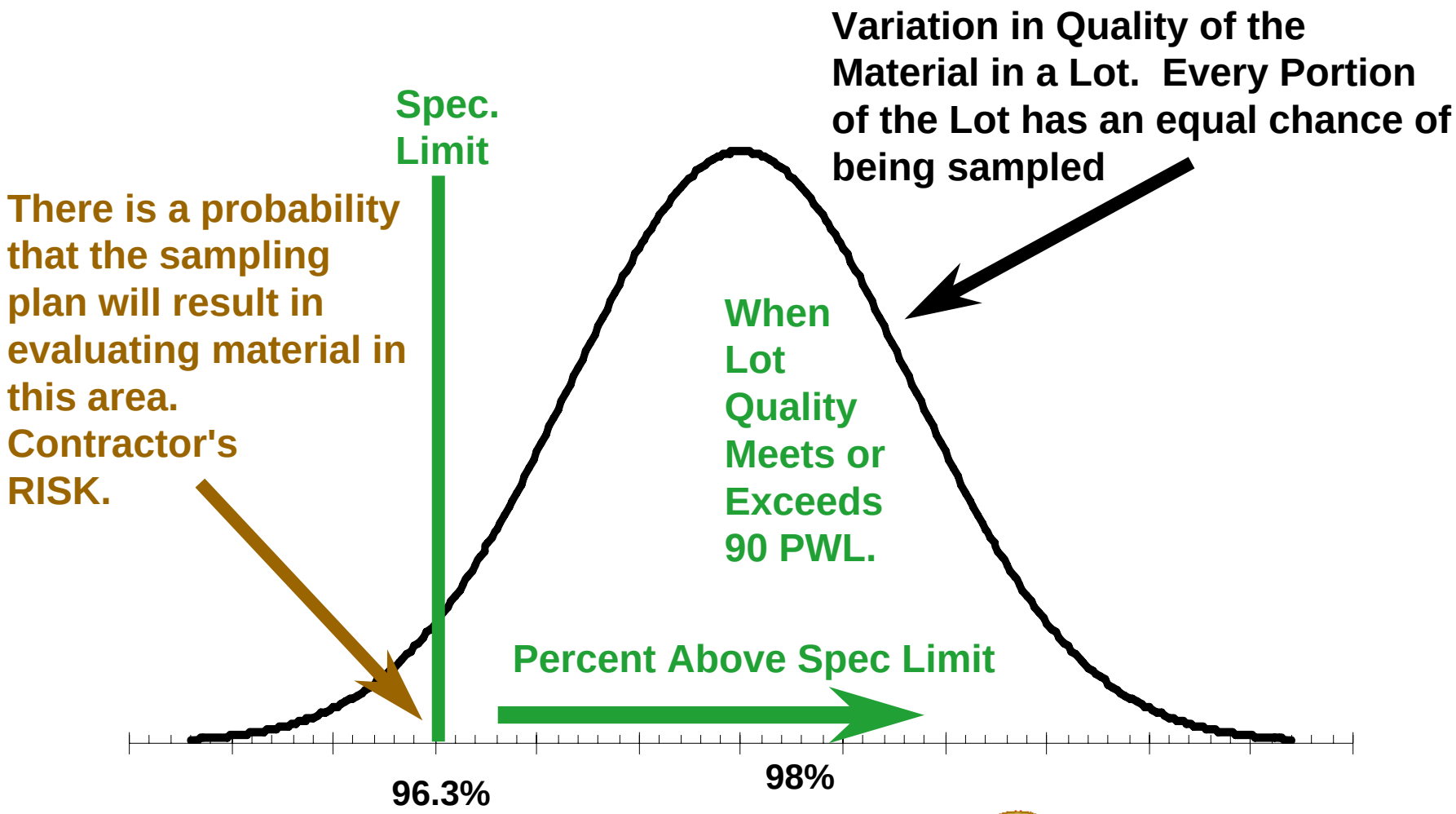
Quality Control—Hot Mix and PCC

- Addresses labs and technicians.
- Processes include lab production, plant production, and field placement.
- Some processes require the Contractor to use statistical quality control measures (run charts and range charts).

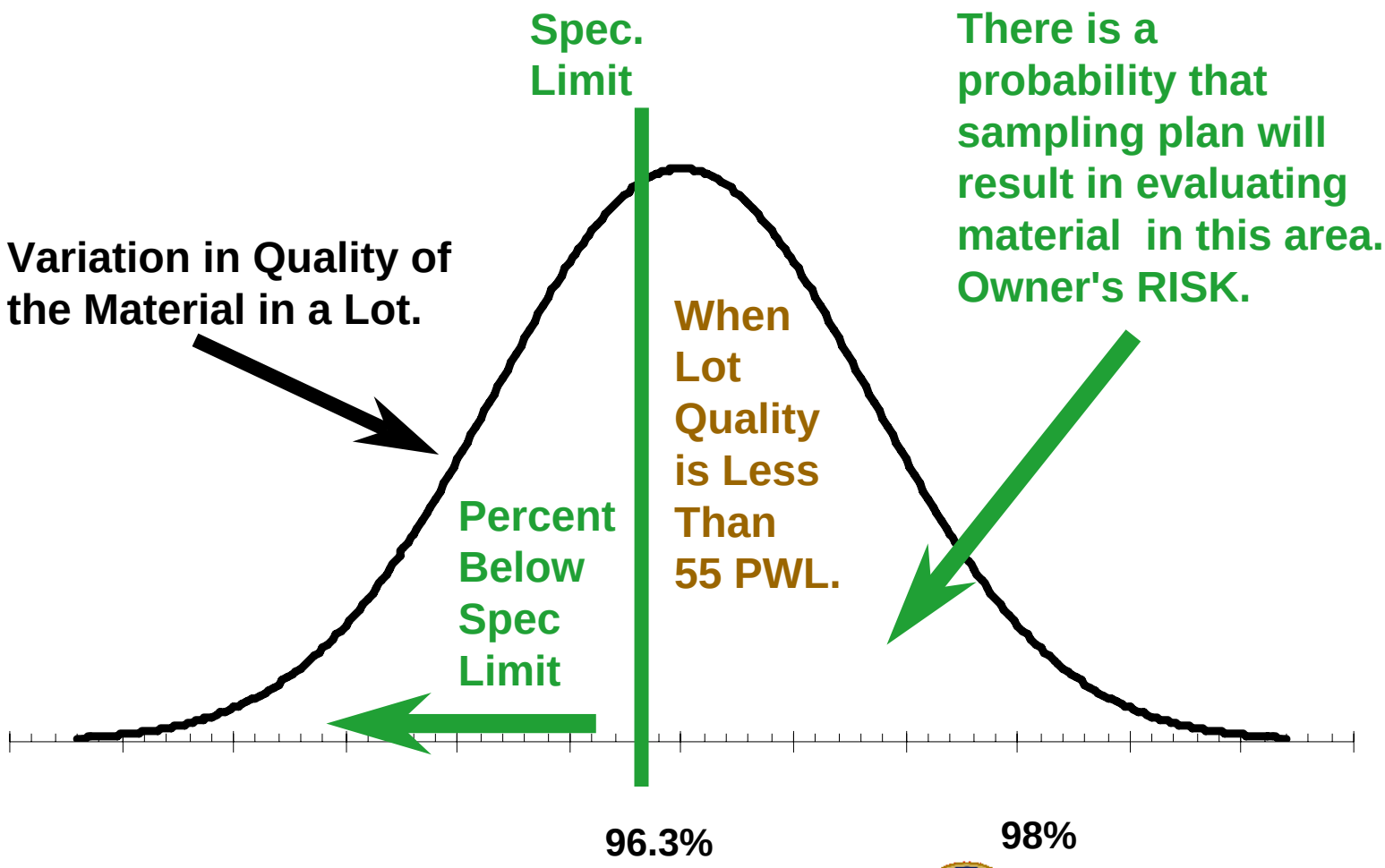
FAA Acceptable Quality

- Item P-401 and Item P-501--FAA assumes process control parameters that are “not unreasonable” for mat density, joint density, air voids, strength, and thickness.
- All acceptance criteria is based on processes with variation in quality conforming to a normal “bell” curve.
- Each day’s production is evaluated and pay is based on daily evaluation of 4 random samples.

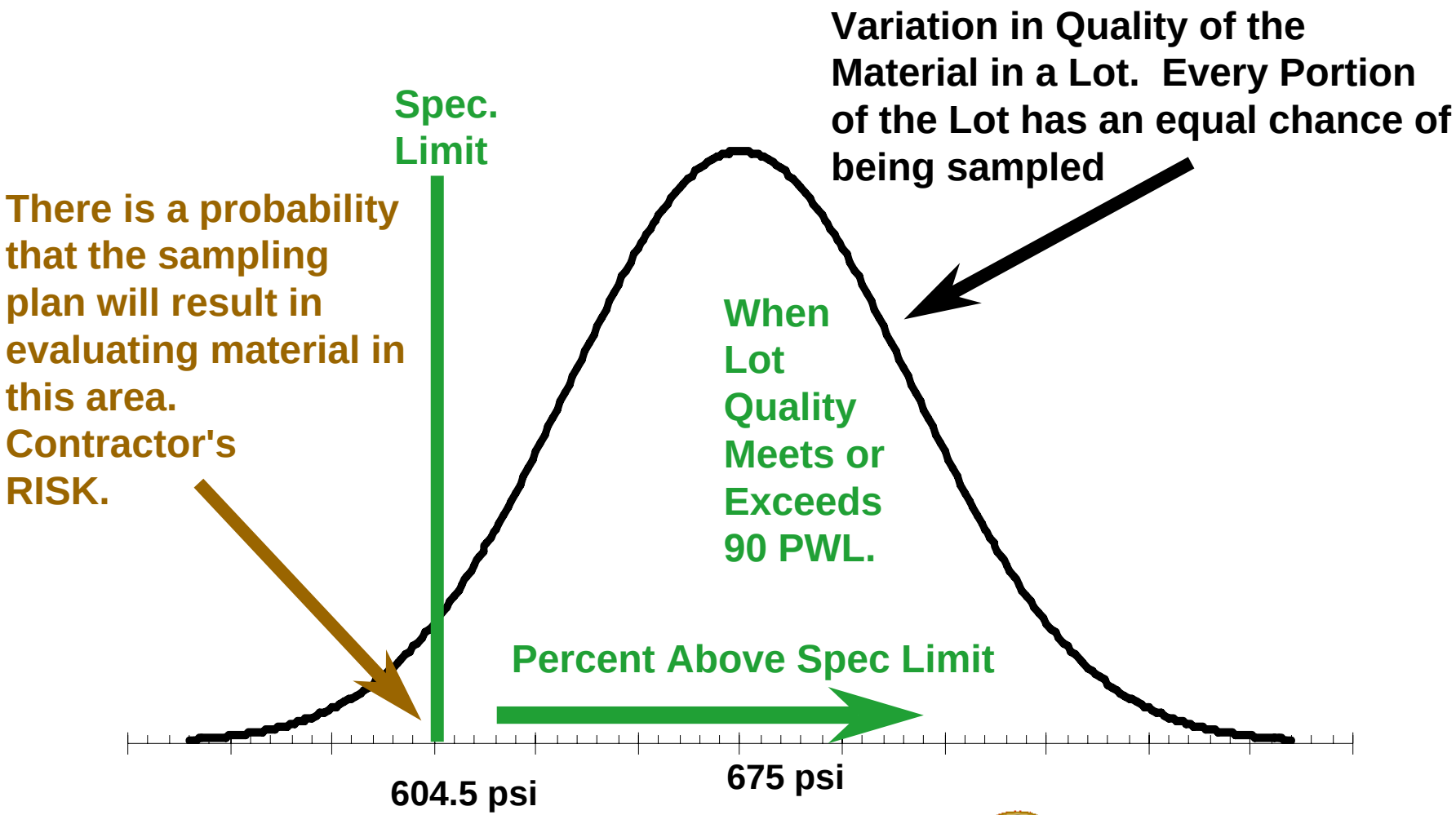
Risk at Acceptable Quality P-401



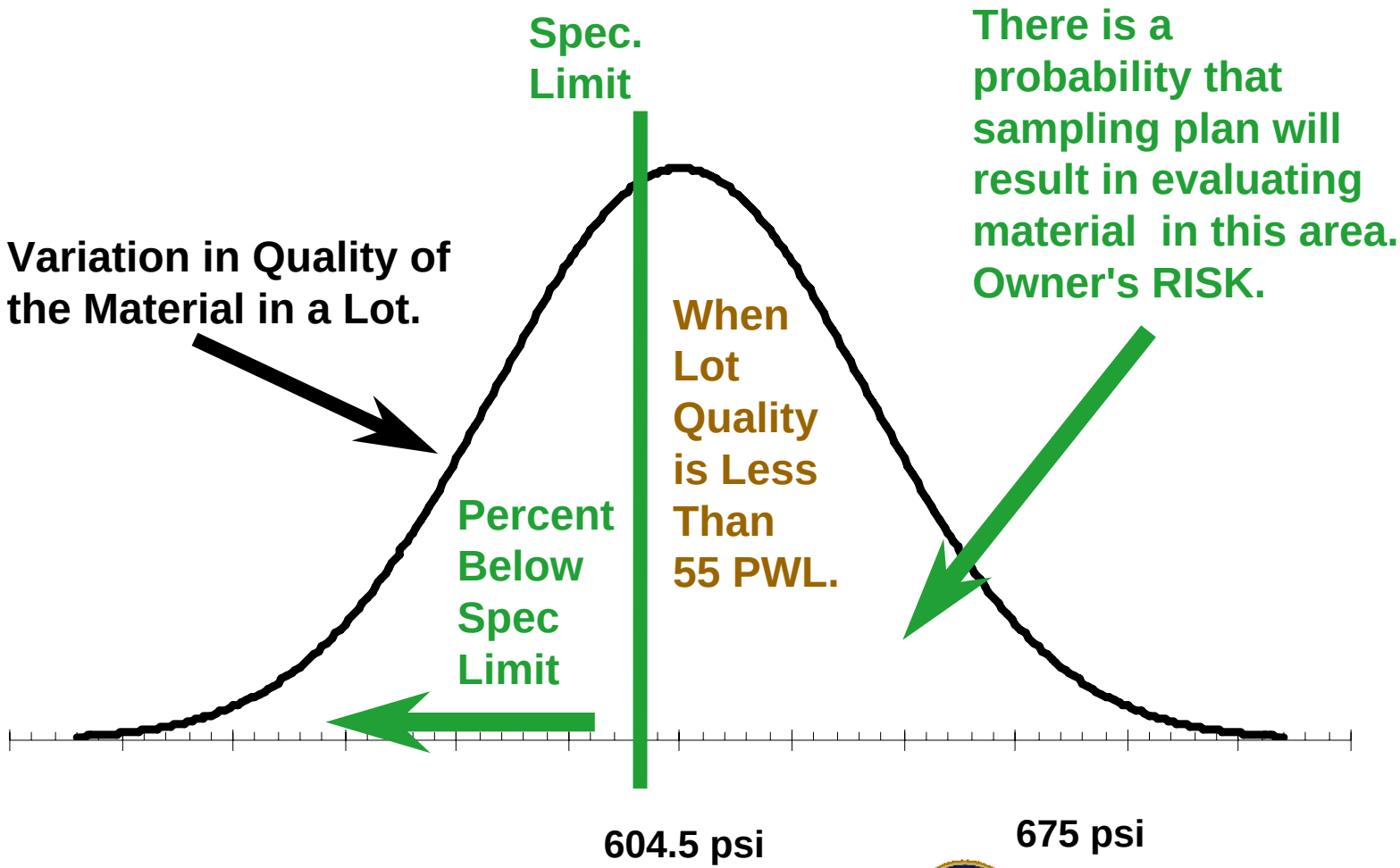
Risk at Rejectable Quality P-401



Risk at Acceptable Quality P-501



Risk at Rejectable Quality P-501



FAA Pay Adjustment Schedule Helps Balance Risk Levels

Percentage of Material Within Specification Limits (PWL)	Lot Pay Factor (Percent of Contract Unit Price)
96-100	106
90 - 95	PWL + 10
75 - 90	0.5 PWL + 55
55 - 74	1.4 PWL - 12
Below 55	Reject

Quality Level "Q" vs. "z"
Small Sample Theory

Quality Level "Q" = $\frac{\text{Lot Average - Lower Spec. Limit}}{\text{Lot Standard Deviation}}$

Small Sample Theory:

At 90 PWL "Q" = 1.200 when sample size, n = 4

At 90 PWL "Q" = 1.254 when sample size, n = 8

At 90 PWL "Q" = 1.267 when sample size, n = 16

At 90 PWL "Q" = 1.275 when sample size, n = 32

At 90 PWL "Q" = 1.278 when sample size, n = 64

At 90 PWL "Q" = z = 1.282 when sample size, n = infinity

PWL Acceptance Limits

$$Q = \frac{\text{Lot Average} - \text{Lower Spec. Limit}}{\text{Lot Standard Deviation}}$$

4 sublots per LOT:

At 90 PWL Q = 1.200 for n=4

POPULATION:

At 90 PWL Q = z = 1.282 for $n = \infty$

Item P-401 Acceptance Limits

$$z = \frac{\text{Population Average - Lower Spec. Limit}}{\text{Population Standard Deviation}}$$

Stability $\frac{2150 - 1800}{270} = 1.30 > 1.28$

Mat Density $\frac{98.0 - 96.3}{1.3} = 1.32 > 1.28$

Joint Density $\frac{96 - 93.3}{2.1} = 1.29 > 1.28$

Air Voids $\frac{5 - 4.2}{0.65} = 1.23$ $\frac{2.8 - 2}{0.65} = 1.23$

Outlier Check ASTM E 178

Outlier Determination for Mat Density.

Density of four random cores taken from Lot

98.9 Average = 97.65
98.5 Sample s = 1.79
98.2 n = 4
95.0 PWL = 76 (93% lot pay factor)

$$Q = \frac{\text{Lot Average} - \text{Lower Spec. Limit}}{\text{Lot Standard Deviation}}$$

Outlier Check ASTM E 178

Outlier Determination for Mat Density.

E-78 with n=4, 5 percent significance level, critical value for test criterion= 1.463
Compare

Max (98.9 - 97.65) / 1.79 = 0.70 < 1.463
No

Min (97.65 – 95.0) / 1.79 = 1.48 > 1.463
Yes

Outlier Check ASTM E 178

Recalculate PWL after eliminating outlier

Density of 3 random cores taken from Lot A. 98.9

Average = 98.53

98.5 Sample s = 0.351

98.2 n = 3

PWL = 100 (106% lot pay factor)

NOTE: Outliers exist if:

Density greater than (97.65+1.463x1.79), or

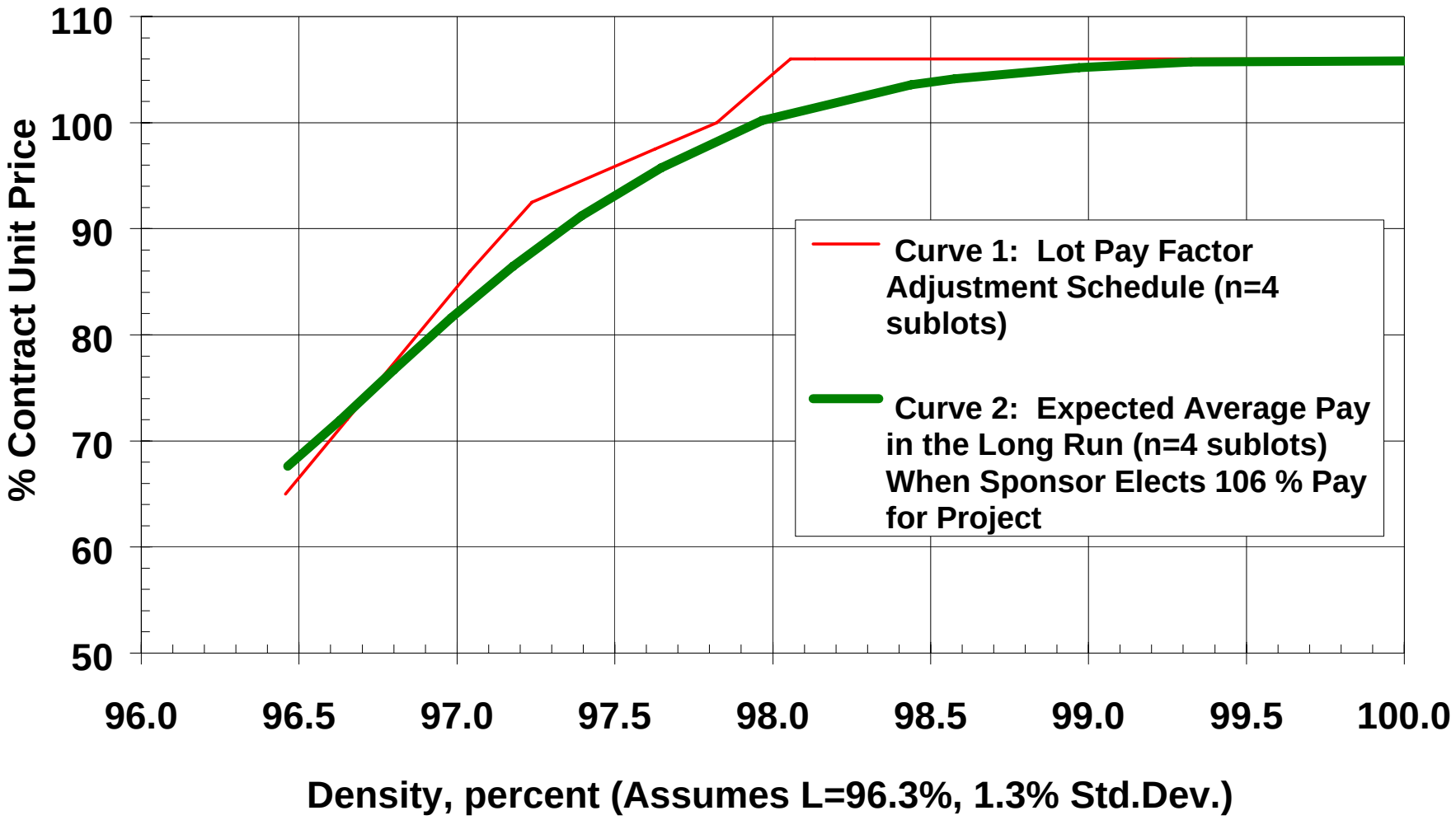
Density less than (97.65-1.463x1.79)

Lot Average +/- Test Criterion*Lot Standard Deviation are Critical Values

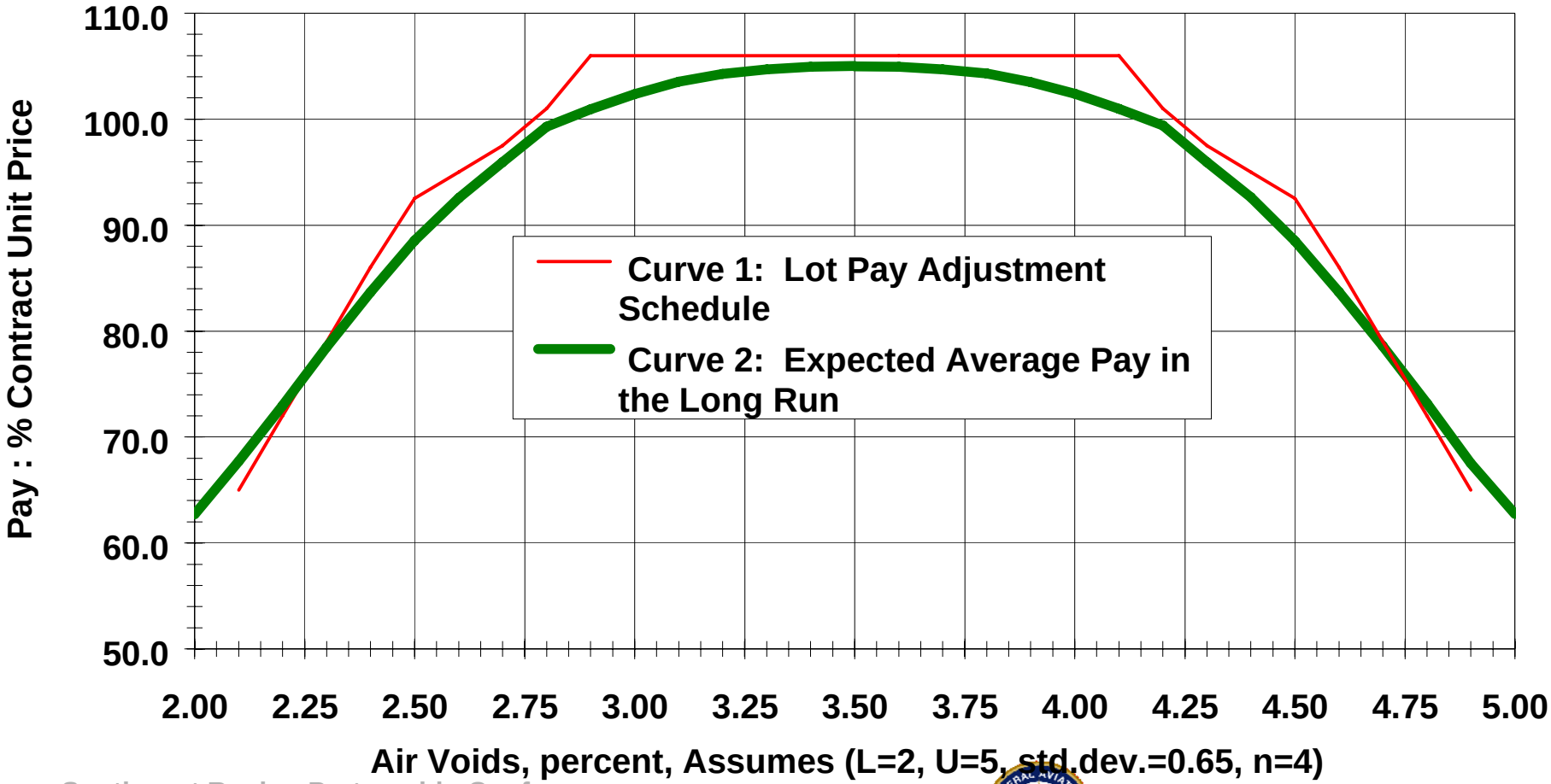
Pay Adjustment Schedule, e.g. Density and Air Voids, Item P-401

Lot Density 90 PWL or Above AND Lot Air Void PWL is:			Lot Density 55-89 PWL AND Lot Air Void PWL is:			Lot Density Below 55 PWL AND Lot Air Void PWL is:		
90 or Above	55-89	Below 55	90 or Above	55-89	Below 55	90 or Above	55-89	Below 55
Lot Pay Factor is:			Lot Pay Factor is:			Lot Pay Factor is:		
Higher of the two	Product of the two	50% and total project payment reduced	Product of the two	Lower of the two	50% and total project payment reduced	50% and total project payment reduced		

ITEM P- 401 Lot Pay Factor vs. Density Required: Example



P- 401 Lot Pay Factor vs. Air Voids Required: Example



Expected Pay versus Quality Levels
SPONSOR ELECTS 106 % PAY

		Expected Pay Factor at Production PWL Average in Long Run for n=3 thru n=8					
PWL	Lot Pay Factor	n=3	n=4	n=5	n=6	n=7	n=8
99+	106.0	106.0	106.0	106.0	106.0	106.0	106.0
99	106.0	105.7	105.7	105.9	105.8	105.9	105.9
98	106.0	105.3	105.2	105.4	105.4	105.5	105.5
96	106.0	104.0	104.1	104.4	104.4	104.4	104.5
95	105.0	103.1	103.6	103.9	103.8	103.9	104.0
90 AQL	100.0	100.1	100.2	100.8	100.8	101.0	101.0
85	97.5	94.5	96.3	97.4	97.4	97.5	97.6
80	95.0	89.9	91.3	92.5	92.6	93.0	93.3
75	92.5	85.4	86.5	87.5	87.7	88.2	88.5
70	86.0	80.8	81.6	82.1	82.4	82.6	83.0
65	79.0	76.4	76.7	76.6	76.9	77.0	77.1
60	72.0	72.1	72.0	71.1	71.6	71.4	71.3
55 RQL	65.0	68.2	67.7	66.2	66.5	66.0	65.7

Expected Pay versus Quality Levels
SPONSOR ELECTS 100 % PAY

		Expected Pay Factor at Production PWL Average in Long Run for n=3 thru n=8					
PWL	Lot Pay Factor	n=3	n=4	n=5	n=6	n=7	n=8
99+	106.0	100.0	100.0	100.0	100.0	100.0	100.0
99	106.0	100.0	100.0	100.0	100.0	100.0	100.0
98	106.0	100.0	100.0	100.0	100.0	100.0	100.0
96	106.0	100.0	100.0	100.0	100.0	100.0	100.0
95	105.0	100.0	100.0	100.0	100.0	100.0	100.0
90 AQL	100.0	100.0	100.0	100.0	100.0	100.0	100.0
85	97.5	94.5	96.3	97.4	97.4	97.5	97.6
80	95.0	89.9	91.3	92.5	92.6	93.0	93.3
75	92.5	85.4	86.5	87.5	87.7	88.2	88.5
70	86.0	80.8	81.6	82.1	82.4	82.6	83.0
65	79.0	76.4	76.7	76.6	76.9	77.0	77.1
60	72.0	72.1	72.0	71.1	71.6	71.4	71.3
55 RQL	65.0	68.2	67.7	66.2	66.5	66.0	65.7

FROM Engr. Brief No. 56, Table 4.4

PWL	Probability of Achieving a Lot Pay Factor of: 106	≥100	≥97.5	≥95	≥92.5	Production Values Needed to Achieve Quality Level, Using FAA Model Assumptions: Item P-401 Density μ =98.0% σ =1.3% L=96.3%	Item P-501 Strength μ =675 σ =55 L=604.5
99	0.93	0.96	0.98	0.99	1.00	99.32	732
98	0.87	0.92	0.96	0.98	0.99	98.97	717
97	0.81	0.88	0.93	0.96	0.98	98.75	708
96	0.76	0.84	0.90	0.94	0.97	98.58	701
95	0.72	0.80	0.86	0.92	0.96	98.44	695
94	0.68	0.76	0.83	0.89	0.94	98.32	690
93	0.64	0.73	0.80	0.87	0.92	98.22	686
92	0.60	0.69	0.77	0.84	0.90	98.13	682
91	0.57	0.66	0.74	0.81	0.88	98.04	678
90	0.53	0.63	0.71	0.79	0.86	97.97	675

FAA ACCEPTANCE –Lot pay equation has an advantage up to 96 PWL

Lot-Basis, n=4 sublots per lot.

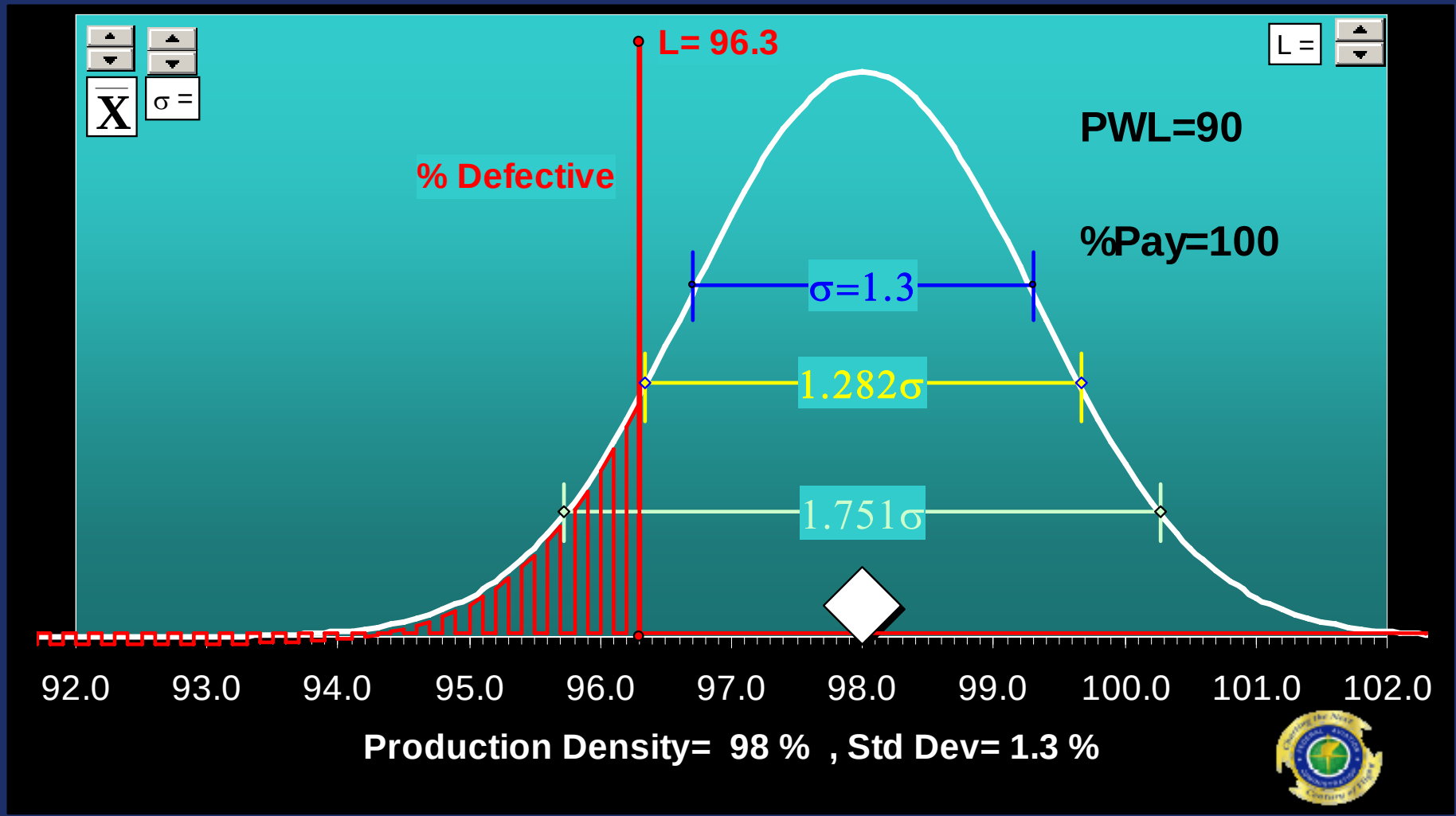
Mat Density– Contractor target >=98.5%

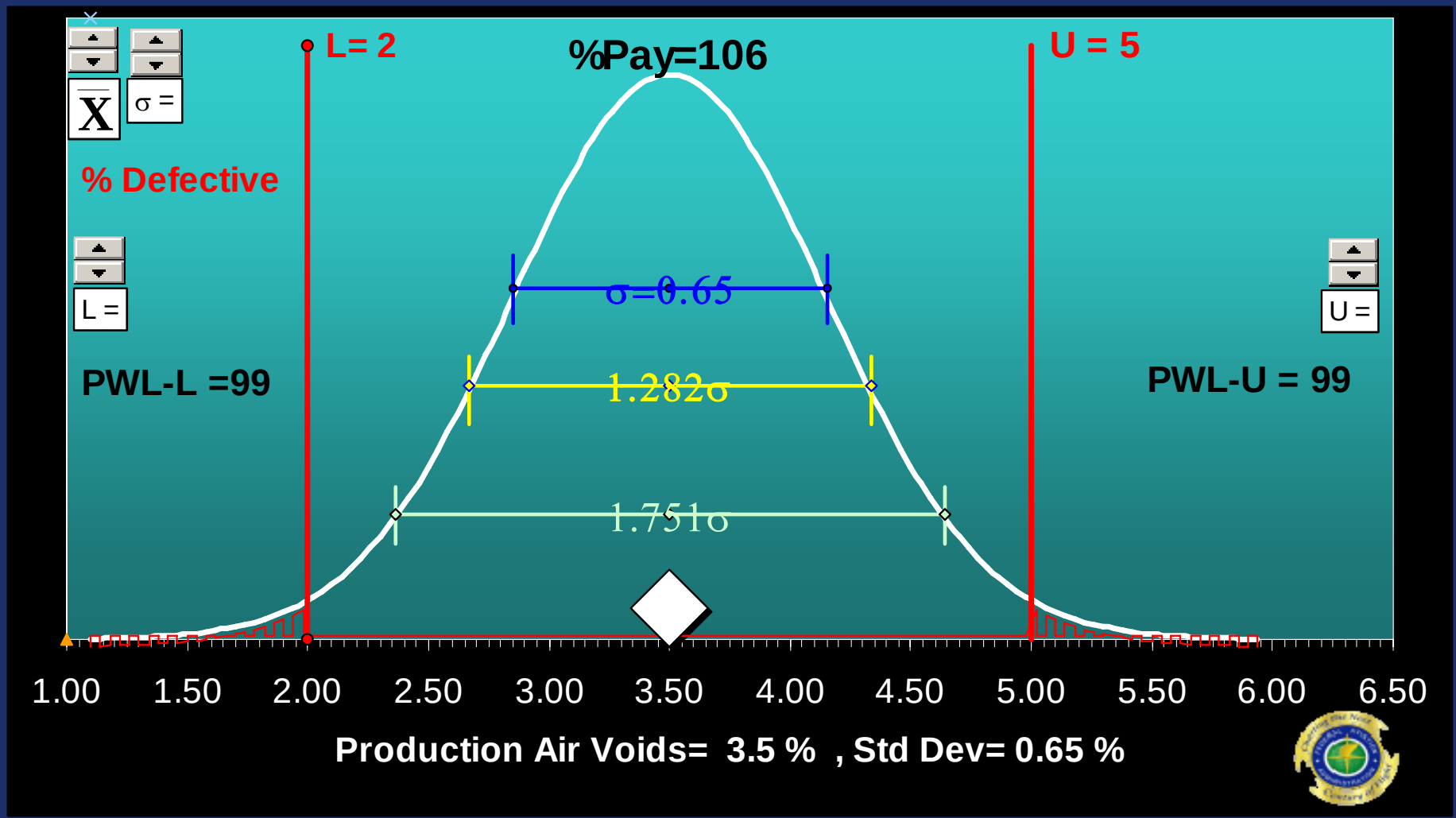
Joint Density – Contractor target >=96.5%

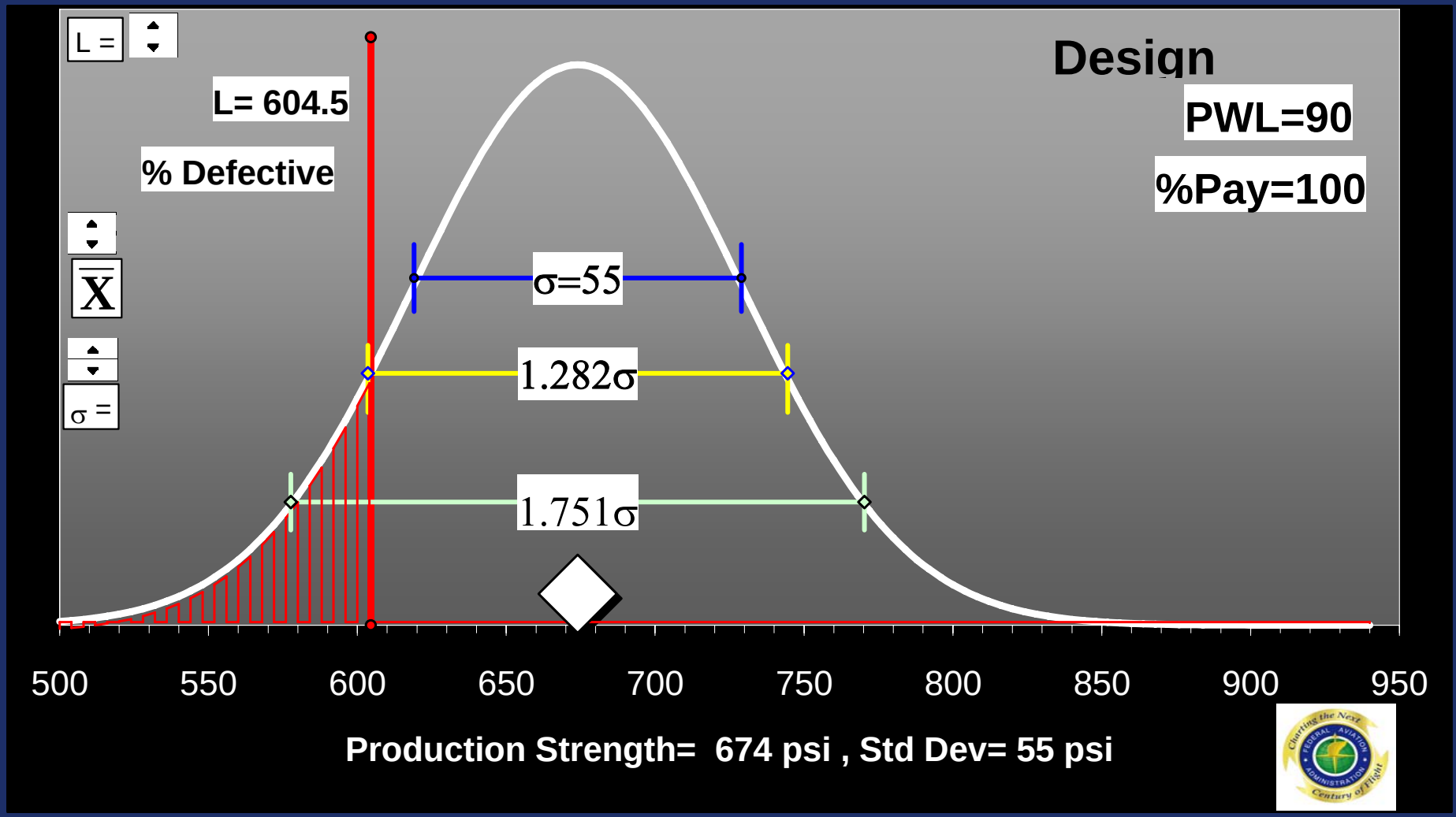
Air Voids – Contractor target ~ 3.5%

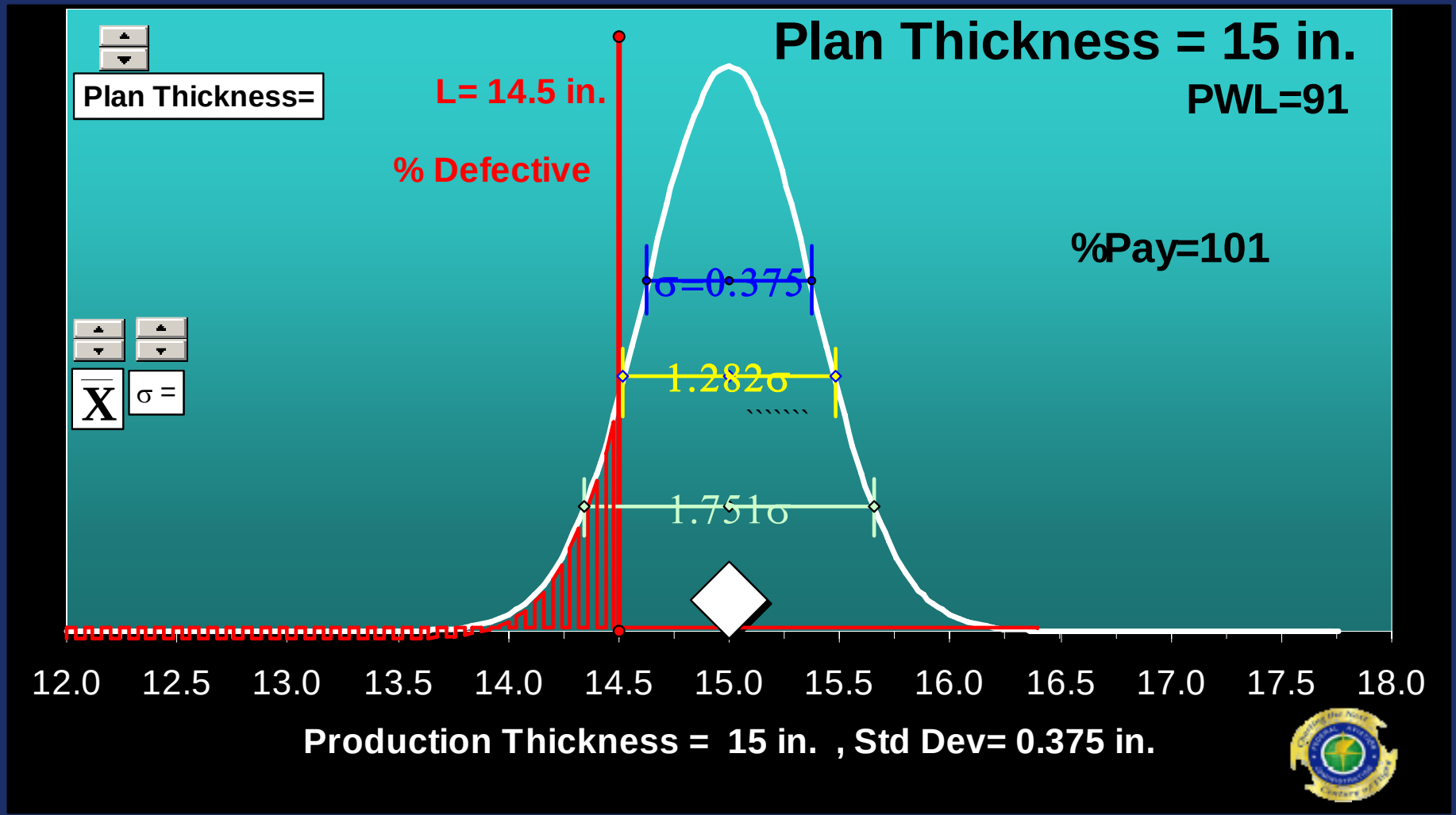
Strength –Achieve 8.5% Coefficient of Variability or Increase Over design Amount.

Thickness -- 3/8” or better.


L= 96.3
L =
PWL=90
%Pay=100
% Defective
σ=1.3
1.282σ
1.751σ
92.0
93.0
94.0
95.0
96.0
97.0
98.0
99.0
100.0
101.0
102.0
Production Density= 98 % , Std Dev= 1.3 %

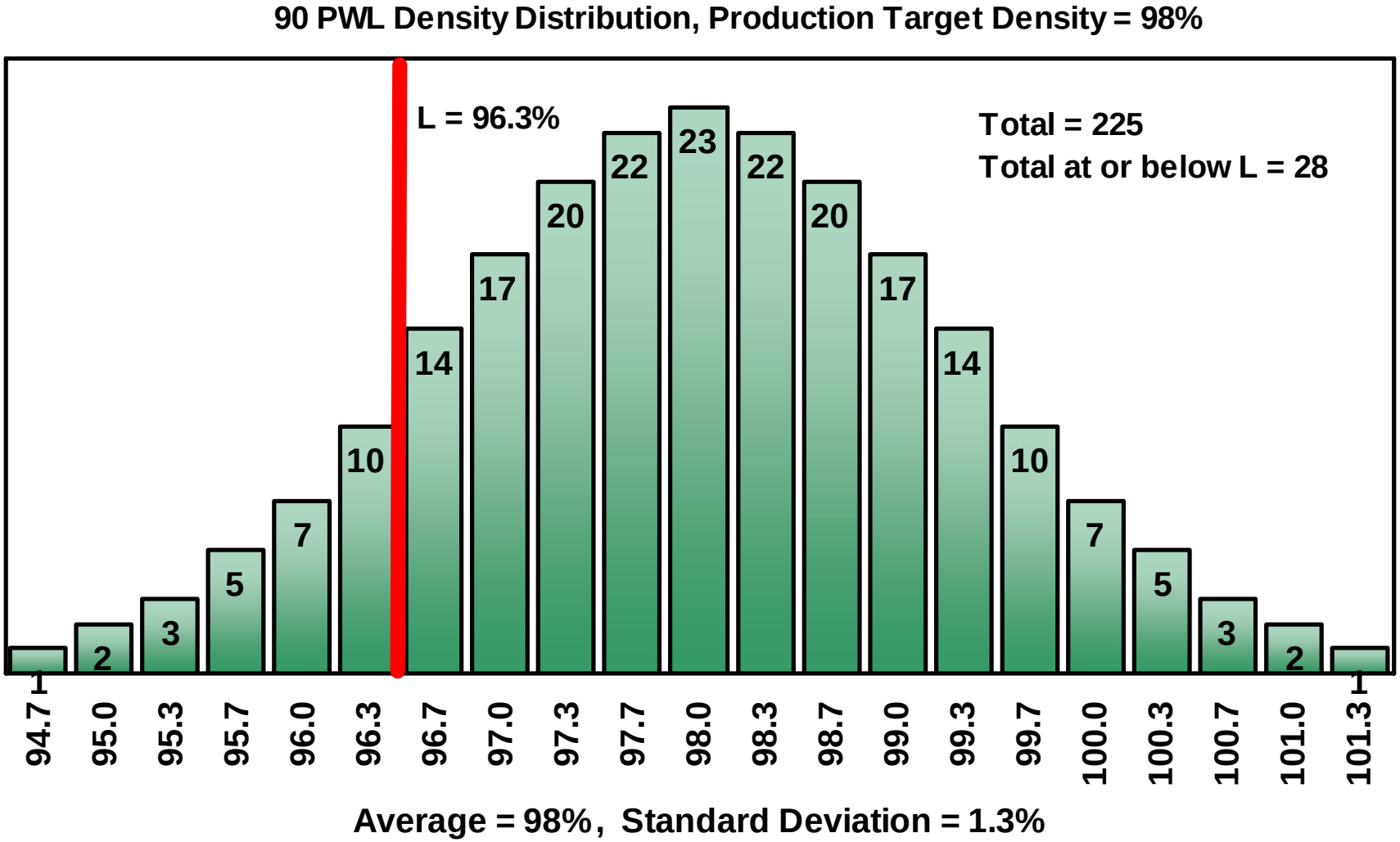

L= 2
%Pay=106
U = 5
X
σ =
% Defective
L =
U =
PWL-L =99
PWL-U = 99
σ=0.65
1.282σ
1.751σ
1.00
1.50
2.00
2.50
3.00
3.50
4.00
4.50
5.00
5.50
6.00
6.50
Production Air Voids= 3.5 % , Std Dev= 0.65 %


L =
L= 604.5
% Defective
Design
PWL=90
%Pay=100
σ=55
1.282σ
1.751σ
σ =
500
550
600
650
700
750
800
850
900
950
Production Strength= 674 psi , Std Dev= 55 psi

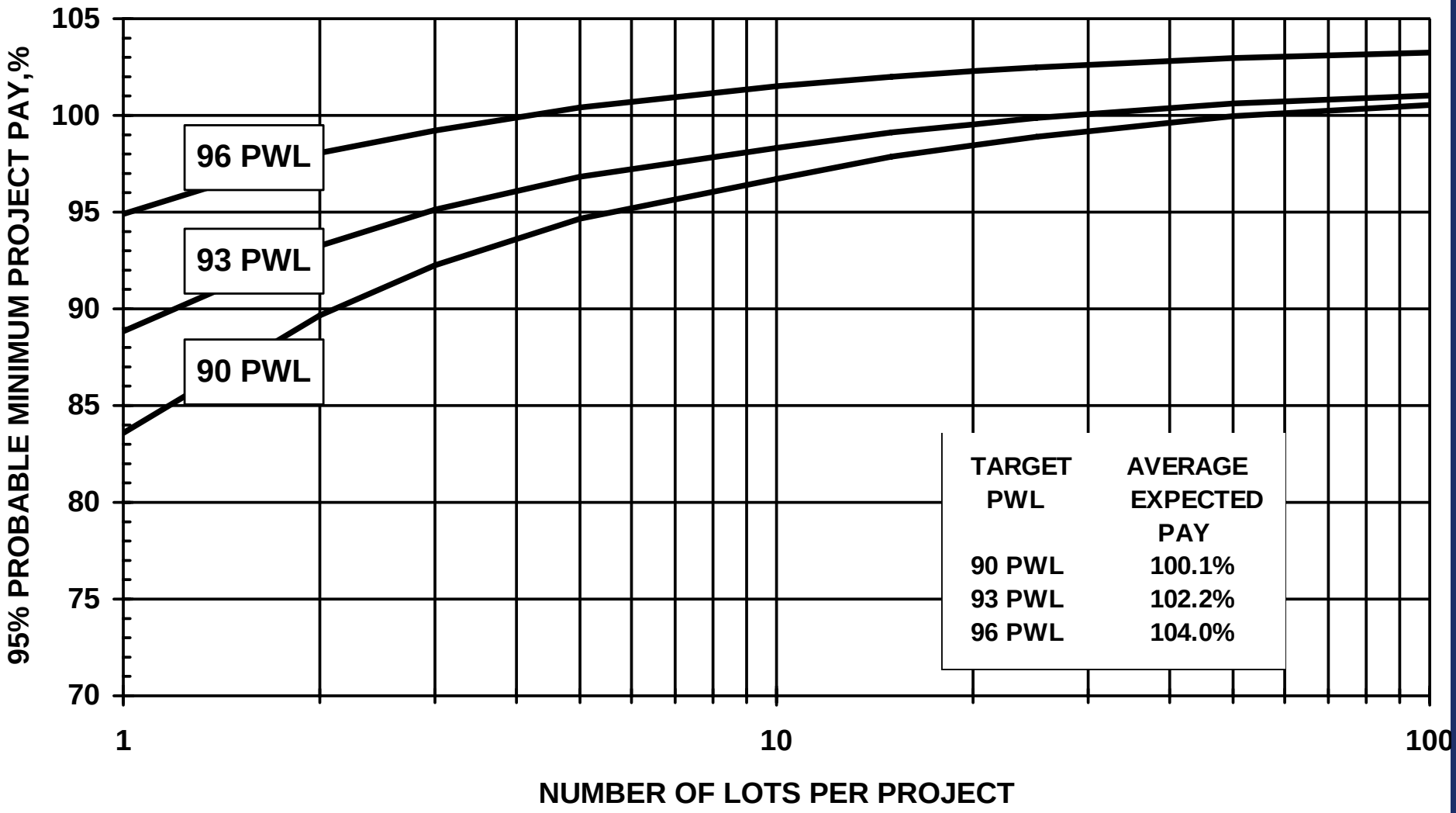

Plan Thickness = 15 in.
PWL=91
Plan Thickness=
L= 14.5 in.
% Defective
%Pay=101
σ=0.375
1.282σ
1.751σ
X
σ =
12.0 12.5 13.0 13.5 14.0 14.5 15.0 15.5 16.0 16.5 17.0 17.5 18.0
Production Thickness = 15 in. , Std Dev= 0.375 in.

Workshop Interaction

Workshop Interaction



NUMBER OF LOTS PER PROJECT VS. MINIMUM EXPECTED PAY
CONTRACTOR TARGETS PRODUCTION AT 90 PWL, 93 PWL, 96 PWL
95% PROBABILITY CURVES



TARGET PWL	AVERAGE EXPECTED PAY
90 PWL	100.1%
93 PWL	102.2%
96 PWL	104.0%

Estimating the Standard Deviation of a Population (σ)—Analogous to estimating the Target Production Standard Deviation

When we wish to refer to the standard deviation of an underlying universe or parent population (target production), we use the symbol σ. In the construction process the true value of σ (target production standard deviation) is usually unknown. However, it is possible to estimate σ by using a (lot) sample (or series of (lots) samples) as follows:

$\sigma = s / c_2$

Where s is the standard deviation of a (lot) sample of a given size (e.g. n=4), and c_2, is a factor which varies with (lot) sample size as shown in the table. E.g., c_2 for a (lot) sample size, n = 4, is 0.7979.

Sample Size	d_2	c_2
3	1.693	0.7236
4	2.059	0.7979
5	2.326	0.8407
6	2.534	0.8686
7	2.704	0.8882
8	2.847	0.9027

Excerpt from Statistical Quality Control Handbook, Eleventh Printing—Copyright 1956 by Western Electric Co, Inc, Renewed 1984 by AT&T Technologies, Inc., page 131 paraphrased to apply to Lot acceptance.